

# Comparison of the multivariate and bivariate analysis of corporate competitiveness factors synergy

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## Abstract

Corporate competitiveness is influenced by a number of factors. Their impact is not partial, but synergistic. It is necessary to respect the phenomenon of synergy consistently when examining which of these potential competitiveness attributes can really function as these factors. Consequently, feature selection and classification methods of statistical pattern recognition have been used for the multivariate statistical analysis of and search for competitiveness factors. The calculations conducted herein show that the Sequential Forward Floating Search method in combination with *k*-Nearest Neighbours classification is capable of capturing the synergistic effect of the whole set of factors, providing much better results than simple bivariate analysis methods that test only the partial effects of individual factors.

## Keywords

Competitiveness, competitiveness factors, corporate financial performance, multidimensional statistical methods, Sequential Forward Floating Search, synergy, *k*-Nearest Neighbours.

**JEL Classification:** C49, L25, M10

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# Comparison of the multivariate and bivariate analysis of corporate competitiveness factors synergy

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## 1. Introduction

The issue of searching for corporate competitiveness factors represents an attractive and very timely matter for both practice and theory. Many works deal with it. Summarising studies quote dozens of works (e.g. 82 studies in the meta-analysis by Allouche and Laroche, 2005) and bibliographic databases index thousands of articles on this topic yearly. However, these works do not present a unified school of thought as they differ in their approaches to the issue, terminology used, application of methods and reasons for dealing with the issue as well as the credibility of the obtained results and ways of their application (Ambastha and Momaya, 2004).

In the given context, there are two basic topics, namely

- competitiveness of businesses (or corporate competitiveness) and
- factors of their competitiveness.

In this article, we deal with both of them; however, the focus involves the issue of competitiveness factors, while competitiveness itself is only a broader framework for the presented solution.

The term *competitiveness* is very ambiguous, and therefore understanding its significance is far from uniform even in the scientific literature. Below, we present some of the concepts and then formulate our own concept to suit the subject of our research as appropriately as possible.

Within the context of corporate competitiveness factors, i.e. the causes that influence competitiveness substantially, we focus on one of the key issues – the synergy problem. This refers to the reality that a firm's competitiveness is not a result of a partial effect of individual factors, but of their synergistic effect. This is often mentioned in the literature focused on mergers or inter-company and intra-company cooperation (Carter, 1977; Williamson and Verdin, 1992), while papers focused on other potential sources of competitive advantage view competitiveness as a multidimensional concept (Fraj-Andrés et al., 2008).

The goal of this paper is therefore to verify these synergy effects by presenting appropriate research results.

To operationalise this objective, the following hypothesis was formulated: *The dependence of corporate competitiveness on a group of factors operating in their mutual connection is significantly higher than when these factors operate partially.*

The validation of this hypothesis is conducted here in these steps. First, the current state of knowledge in the field of corporate competitiveness and its factors are analysed. Second, the concept of competitiveness is operationalised, data representing potential factors are described and selected methods (Sequential Forward Floating Search (SFFS) and *k*-Nearest Neighbours (*k*NN)) are introduced. Lastly, the results are presented and a conclusion is drawn.

The importance of this research does not lie in the simple verification of generally accepted statements expressed in the hypothesis mentioned above, but by the attempt to quantify the synergistic effect.

## 2. Competitiveness

The concept of corporate competitiveness has been a very widely used term for many years not only in the professional field, but also beyond, especially in the context of various opinions, views or statements of a rather ideological and political nature (e.g. the Lisbon strategy). Competitiveness refers to businesses, industries, regions, states or state groups. In this situation, the perception of the meaning of this concept becomes very ambiguous or even vague.

The subject of our interest involves the sphere of businesses, where the concept of competitiveness takes a more concrete form, although even here the perception of this concept is not clear and definite. Cellini and Soci (2002) state that *a firm is competitive if it can serve a market*. Molina et al. (2004) assume that competitiveness will be reflected by maintaining or increasing sales volume compared with market development. Krugman and Hatsopoulos (1987) perceive corporate competitiveness as a competition

for markets, and they measure it by market share or profitability. In the Czech Republic, Jirásek (2000) defines competitiveness as *a term expressing a market potential of a business, sector, country in conflict with other businesses, sectors, countries for a position in the market*. Klvačová (2008), who respects the stakeholder approach in her definition of corporate competitiveness, expresses herself quite clearly. In her opinion, *a business is considered to be competitive if it is able to stay in the market and increase its market share if possible. At the same time, it must be able to fulfil its obligations to its environment: pay wages to its employees, pay dividends to shareholders, properly pay taxes to the state, repay loans to banks and pay suppliers for raw materials, other material, intermediate products, machinery and equipment*. Bartes (2011) expresses himself clearly and briefly, i.e. in a relatively operationalisable way by defining a competitive business as *successful in the market*.

It is not the aim of this paper to present an analysis of the different concepts of competitiveness as they appear in the literature. However, it is necessary to state how this term is understood in the context of the issue we focus on. In order to evaluate the competitiveness of a company, we work with its traditional concept as the ability to achieve market success (see e.g. Mathis et al., 1988).

It stems from the nature of the corporate competitiveness concept that a company is able to survive in competition with its competitors in a market (see Slaný et al., 2006). A company that is able to compete will retain the existing market or can enter a new market. A company unable to compete will not retain the existing market or cannot enter a new market.

Still, the competitiveness concept itself tells us nothing about how a company is successful in a market. It only says, fundamentally speaking, that a company is so good that it can compete in a given market. However, it is evident that in the context of focusing on our issue, we cannot deal only with whether a company is able to compete in a given market, but it is also necessary to analyse how successfully. This leads us to the requirement of operationalisation. We base our work on the following scheme:

- Competitiveness is a company's potential to succeed in competition with other businesses.
- The result of this competition is the success (or failure) of a company expressed by its performance and measured by its financial indicators.
- The relationship between competitiveness and the performance of a company is a relationship between cause and effect, considering the feedback, i.e. the impact of current performance on future competitiveness.

Given the nature of our task, in relation to the opinions of some authors and with regard to the available data, we handle competitiveness as financial performance. In this respect, Valecký and Slivková (2012) propose in their study to classify businesses using a combination of return on assets (ROA) indicators, total indebtedness, the share of loans and liabilities, and immediate liquidity. Suchánek and Špalek (2012) use a combination of profitability, activity, indebtedness and liquidity. We have accepted the recommendations of the study by Šiška and Lízalová (2011) and we thus measure corporate financial performance with two indicators:

- ROA and
- growth of assets.

Within the given meaning of the concept, we can say that a company with a higher ROA and higher assets growth than other companies also has higher financial performance and thus it is more competitive than other companies. Analysing the reasons why it achieves higher financial performance, or competitiveness, falls within the second of the above-mentioned topics, i.e. the factors of the competitiveness of companies.

### 3. Competitiveness factors

Similar to the case of the competitiveness of companies, even for their competitiveness factors the literature offers a variety of approaches. The indicators that are traditionally perceived as competitiveness factors include price and quality (Schumpeter, 1943; cited in Jirásek, 2000). In the 1980s, Michael Porter (1980, 1985) focused the attention of the professional community primarily on the structure of a company's microenvironment. But as this approach explained differences in the competitiveness of companies in one industry rather than across industries (Schmalensee, 1985; Cool and Schendel, 1988), experts' attention turned to internal factors and thus gave rise to the Resource-Based View (constituted in Wernerfelt, 1984). A range of authors were able to gradually prove the influence of various factors on business performance, such as spending on R&D (Lev and Zarowin, 1998), expenses for advertising purposes (Chauvin and Hirschey, 1993), brands (Kim and Chung, 1997), human capital (Wright et al., 1994; Truss and Gratton, 1994; Hand, 1998; Huselid, 1999) and the efficiency of decision making (Ulrich and Lake, 1990; Molina et al., 2004). We note that these cases involve primarily intangible assets, or rather immaterial values. As Barney (1991), Grant (1991) and Peteraf (1993) note, these values must be heterogeneous, rare, valuable, difficult to reproduce and impossible to replace if they are to be considered to be factors in higher corporate competitiveness.

It is clear from this brief summary that the competitiveness factors of companies can stem from the macroenvironment, microenvironment as well as a company's internal environment. They can be of both tangible and intangible nature; in addition, their characteristics (e.g., scarcity, inimitability, etc.) have to be taken into account.

Moreover, it should be noted that a factor and competitiveness cannot be understood only in a simple relationship of cause and effect, but usually as an entire chain, where the cause (factor) itself is often the result of a preceding cause. In this sense, factors have to be perceived as either direct or indirect. The relationships in these chains need not be only sequential but also of a feedback nature.

The key issue of analysing the competitiveness factors of companies is the fact that the competitiveness of a given company is the result of neither the impact of one factor nor the partial effect of several factors, but rather the synergistic effect of the whole set of factors. In addition, this set is not defined generally, but changes according to the conditions of the company. Furthermore, it is impossible to assess generally, or a priori, the value of individual factors in the scope of a better, worse or optimal value of the factor; they always have to be assessed in relation to the values of other factors.

When analysing business practice, we find many examples by which we can illustrate the above-mentioned facts. For example, in an industry where a certain type of certificate is just being introduced, this certificate gradually becomes a factor that has a significant impact on the competitiveness of companies. However, as the number of businesses that receive this certificate grows, its influence gradually slows, subsequently it decreases, and in a situation when a large majority of businesses, or all businesses operating in the given competitive environment, have this factor, its effect is close to zero. In our research, for example, we found that in the construction sector, all companies of the surveyed sample already hold the ISO 9000 certificate, relating to the quality management system, while only 85% of companies hold the ISO 14000 certificate, relating to the environmental management system. As we show below, statistical evaluation confirmed that under the given circumstances the ISO 14000 certificate is a factor of competitiveness, while the ISO 9000 certificate has lost this effect completely.

It can be assumed in another example that the set of competitiveness factors will include *company size*, on the one hand, and the *industry* in which the company operates, on the other. For example, it will be true for the production of passenger cars that a larger company will have (with other conditions being the

same) an advantage over a smaller company. By contrast, in the sector of certain services where the flexibility and adaptability to changing conditions is essential, the relationship could be opposite.

Similarly, we can evaluate, for instance, the amount of funds spent on employee training. It seems that in general, higher funds spent on education create a more qualified workforce, which then becomes a competitive advantage for the company. However, such a relationship is not generally valid, but applies only if the higher qualification is fully usable. Nevertheless, if the qualification of the workforce is higher than is needed for the given job, the effect is negative: workers with higher qualifications are too expensive, their use for unskilled labour leads to their dishonour, loss of motivation and subsequent higher employee turnover.

It would be possible to give more and more examples; however, this is not the goal of this article. Nevertheless, given the considerations it is necessary to realise the complexity of tasks of a given type: even a relatively small number of factors may give rise to a very large number of meaningful combinations of values of these factors that reflect reality, and each of these combinations offers different financial performance, or corporate competitiveness.

Addressing these problems can be approached in two ways. The first is the heuristic approach, largely based on good content knowledge of the issue, relying on the analysis of empirical studies through non-formalised logical reasoning. The second approach represents an exact concept, based on the use of mathematical and statistical methods and techniques.

The analysed literature implies that for the purposes of the search and evaluation of corporate competitiveness factors, there is quite a wide variety of different mathematical and statistical methods and techniques. First, we should mention bivariate techniques. From earlier studies, we can mention White (1986) and his study of the influence of generic strategies on return on investment and sales growth, where he uses the correlation, frequencies and averages, or Hansen and Wernerfelt (1989) researching the influence of economic and organisational factors on ROA using correlations. As far as more recent studies are concerned, we should stress Artiach et al. (2010), who use correlations and t-tests to verify the influence of selected factors on the position of companies in the Dow Jones Sustainability Index, or Liu et al. (2004), who also uses correlations. However, bivariate techniques, because they always analyse only the relationship between two variables, cannot capture the complexity of reality nor the above-mentioned synergistic effect.

Nevertheless, even more advanced methods are used, ranging from multiple regression (Homburg et al., 1999; multiple logistic regression (Kessler, 2007) through structural modelling (Yilmaz et al., 2005) to decision trees (Molina et al., 2004). Unlike bivariate techniques, these procedures test the dependence of diversely measured performance or corporate competitiveness on multiple independent variables. This usually provides a better explanation of the variability in the performance of companies. However, their use requires certain restrictions, such as the normality of the input data or a robust a priori model. Even with decision trees, i.e. a learning method, it is necessary to identify one factor for a start.

#### 4. Data

To validate the above-mentioned hypothesis stating that *the dependence of a company's competitiveness on a group of factors interacting in mutual connections is significantly higher than when these factors act partially*, we chose the following procedural steps:

- Identifying competitiveness factors based on multidimensional analysis methods.
- Evaluating the degree of dependence of corporate competitiveness on this group of factors that operate in mutual relations.
- Evaluating the degree of dependence of corporate competitiveness on these factors that act individually.
- Comparing results.

The experiment was based on data from a relatively extensive empirical investigation. The sample of 432 firms represents companies located in the Czech Republic, operating in the manufacturing industry and construction, whose legal form is a joint-stock company or limited liability company, employing 50 or more people, and with annual sales of more than CZK 1 million. The total number of these companies included about 4500 companies at the time of conducting the empirical survey. Companies in liquidation and companies not publishing their financial statements were ruled out of the survey. The resulting population comprised 2800 businesses. The response rate was roughly 15.4%. The representativeness was proved by Svoboda in Blažek et al. (2007).

A relatively large amount of data was obtained for each company from the Albertina Data database, which collects economic data from financial statements, and the questionnaire that was completed by interviewers during a personal interview with a representative of each company.

#### 5. Corporate performance evaluation

To evaluate the financial performance of companies, six-year time series of the operating profit and total assets of individual companies were used from the Albertina Data database, in accordance with the above-mentioned concept. Based on these data, the following two indicators were calculated for each year:

$$ROA = \frac{OP}{\frac{A_b + A_e}{2}} \cdot 100, \quad (1)$$

$$GA = \frac{A_e - A_b}{A_b} \cdot 100, \quad (2)$$

with *ROA* being return on assets, *OP* operating profit and *GA* growth of assets.  $A_b$  denotes assets at the beginning of the financial year and  $A_e$  assets at the end of the financial year.

Subsequently, the average annual values of these indicators were calculated for the individual companies within the given six-year period. Based on cluster analysis, all the companies of the selected sample were grouped into three basic groups: Group A – highly competitive companies, where the values of both the indicators are above average within the selected sample, Group B – below-average competitive companies, where both the indicators reach below-average but still positive values, and Group C – uncompetitive companies, where the values of both indicators are negative. More information on the manner of grouping can be found in Šiška (2008).

Another extensive set of the characteristics of companies was obtained from questionnaires. These were processed through the primary analysis and were used for the description of the companies in the sample. For the purposes of our experiment, only characteristics (variables) with the potential to become competitiveness factors were selected from this set, based on a factual assessment, supported by the application of simple statistical techniques. Such information was subsequently transformed into a form applicable as an input for the selected method of multidimensional statistical analysis. Specifically, this method was SFFS.

#### 6. Description of the used methods

The problem we face here is selecting a smaller subset of the most informative characteristics from the set of all the measured characteristics (variables, features). The informativeness will be measured here by the ability of a subset to discriminate correctly classes according their financial performance (groups A, B and C). Selecting a smaller subset of characteristics

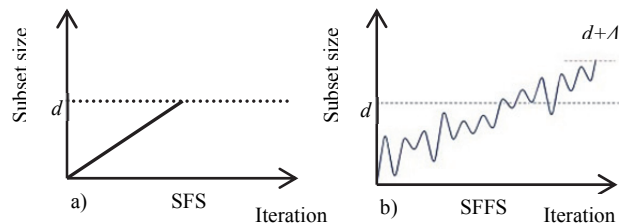
means effectively performing a dimensionality reduction on the original data.

With the ever-increasing specialisation and diversification of scientific disciplines, it is common that similar problems are being tackled in other branches of science, usually without an awareness of the respective research and application communities. It is just this case that the methods developed in a relatively very different field of statistical pattern recognition (SPR) can be used to solve the above-defined problem. SPR is a discipline comprising analytical and adaptive methods for processing large datasets, selecting useful information aimed at reducing the data dimensionality and finally classifying these data. Pattern recognition is actually closely connected with machine learning and thus it is considered to belong to the field of artificial intelligence. One of the fundamental problems of SPR is representing patterns in the reduced number of dimensions, which means a dimensionality reduction. The methods of feature selection are used in SPR to solve this task.

From a formal point of view, this is exactly what we need to do in our search for factors of competitiveness. The problem of finding a subset of  $d$  features (characteristics) out of original  $D$  ( $d \ll D$ ) while maximising an adopted criterion is not an easy one, as generally the features are not statistically independent. The value of  $d$  is either specified beforehand or its determination is a part of the overall solution. Unfortunately, the only optimal and general solution is a full combinatorial search, which (with an increasing number of features) exceeds very soon the possibilities of even the most powerful computers. Therefore, a number of suboptimal search procedures have been developed. The basic feature selection approach builds up a subset of the required number of features incrementally starting with the empty set (*bottom-up* approach) or with the complete set of features and then removes redundant features until  $d$  features remain (*top-down* approach). The simplest widely used choice, the *Sequential Forward (or Backward) Search* SFS (SBS) methods, iteratively adds (removes) one feature at a time to maximise the intermediate criterion value until the required dimensionality is achieved. Earlier sequential methods suffered from the so-called nesting of feature subsets that significantly deteriorated performance. *Floating search algorithms* (Pudil et al., 1994) removed the deficiency of nesting, which resulted in deteriorated performance for SFS and SBS. Floating search algorithms for finding the most informative data have been evaluated independently by university research groups from the US (Jain, 1997) and Japan (Kudo and Sklansky, 2000) as the most powerful among the available ones. Although since then some even more sophisticated search procedures have been developed, the SFFS algorithm

continues to represent the optimal combination of performance and computational efficiency.

The SFFS procedure consists of applying after each forward step (adding the feature that maximises the criterion the most) a number of backward steps (removing the feature, that causes the least criterion decrease) as long as the resulting subsets are better than the previously evaluated ones at that level. Consequently, there are no backward steps at all if the intermediate result at the actual level (of corresponding dimensionality) cannot be improved. The algorithm allows for 'self-controlled backtracking', meaning that it can eventually find good solutions by adjusting the trade-off between forward and backward steps dynamically. In a certain way, it computes only what it needs without any parameter setting (unlike Plus-l-Minus-r algorithms). A formal description of this now classical procedure can be found in Pudil et al. (1994). The floating course of search is illustrated and compared with SFS in Figure 1.



**Figure 1** Comparing the course of search (current subset size depending on time) for SFS and SFFS

The SFFS algorithm has been widely used in many application areas (e.g. medicine, geology, power engineering, finance and banking, economics) both by SFFS authors themselves (about 20 papers in Web of Science; see Pudil et al., 1995, 2008; Somol et al., 1999) or by other researchers worldwide. Pudil et al., 1994, who introduced the SFFS algorithm, is the most cited paper in the history of Elsevier's impacted journal *Pattern Recognition Letters* (1013 citations in Scopus, 875 in Web of Science).

In the problem solved in this paper, the SFFS algorithm is used to identify and select the most informative features. Features are understood as characteristics of a displayed object, which in our case means the variables describing a company. Informativeness is then represented by the extent to which a group of features can correctly classify the object, i.e. the inclusion of a company into Group A, B or C. The SFFS algorithm is able to reduce the set of features to the most informative ones, i.e. competitiveness factors, and, moreover, determine the rate of success of selecting them correctly.

The learning approach used here requires the fulfilment of certain conditions, particularly the minimum ratio of the number of objects to the number of

features (variables, characteristics). This condition (see Jain and Chandrasekar, 1982) applied to our problem can be formulated as

$$\frac{n}{d} > 10, \quad (3)$$

where  $n$  is the number of companies and  $d$  is the number of variables describing each company.

The number of input variables in our experiment was 37; thus, condition (3) is fulfilled in our case:

$$\frac{432}{37} > 10. \quad (4)$$

To assess the informativeness of the tested sets of variables,  $k$ NN is used, which divides objects (companies, in our case) into individual classes (in our case, groups A, B or C based on financial performance) in relation to the nearest neighbours. This means that it evaluates the distance of the examined object to all objects in the training set (i.e. objects whose classification is known), finds the  $k$  nearest neighbours and classifies the examined object according to which class these nearest neighbours belong to. The number of nearest neighbours  $k$  is an optional parameter. As it is not possible to decide clearly and in advance which value of  $k$  should be used, we chose the value of  $k$  variably, i.e. 1, 3 and 5.<sup>1</sup> In this context, we talk about the technique of one, three or five nearest neighbours and use the designation 1NN, 3NN and 5NN. The advantage of the  $k$ NN classifier is that it is non-parametric, easy to implement and has high power decision-making ability.

## 7. Experimental Results

In the search for competitiveness factors, hundreds of experiments were carried out using SFFS on the dataset presented above at the Research Centre for Competitiveness of the Czech Economy.<sup>2</sup> A representative set of results of the SFFS method application is shown in Figure 2. It is clear how the algorithm gradually adds the input variables to the ever-growing group (x-axis), while it uses individual steps to evalu-

ate the value of the informativeness indicator, created by the synergistic effect of the respective group of variables (y-axis). Each of these curves is valid for one of the three selected values of  $k$ , i.e. the techniques of 1NN, 3NN and 5NN. The graph shows a typical dependence between the size of the selected group and the value of the informativeness indicator: first, a rapid growth in informativeness reaching the absolute maximum with the set of three to four variables, followed by a decline. However, this decline is not monotonous; there are certain *swings* associated with the existence of local maxima.

The assessment of the calculated maxima (absolute maximum and local maxima) was no longer the product of the algorithm, but was rather associated with the interpretative phase of the solution. Given the nature of the solved task, it involved a group of 16 selected variables identified in the evaluation by the 5NN technique that reaches a value of informativeness of 0.650. As shown in Table 1, this is not an absolute maximum of informativeness, but a local maximum, which is significantly close to the highest value of informativeness (0.661).

The reason for this choice was the nature of the problem solved. It cannot be assumed that such a complex and complicated phenomenon as the financial performance of companies could be credibly explained merely by a combination of values of three to four variables.

The set of input variables gave rise to a group of 16 variables that – if considered in mutual relations – have the greatest influence on what kind of financial performance a company achieves. For this reason, we consider them in our experiment as the competitiveness factors of the given sample of companies. This included the variables listed in Table 2.

It is true that certain combinations of values of these variables, i.e. competitiveness factors, are shown by highly competitive companies, belonging to Group A, while other combinations of values of these variables are reported by less competitive companies in Group B, and even different combinations are shown by uncompetitive companies in Group C.

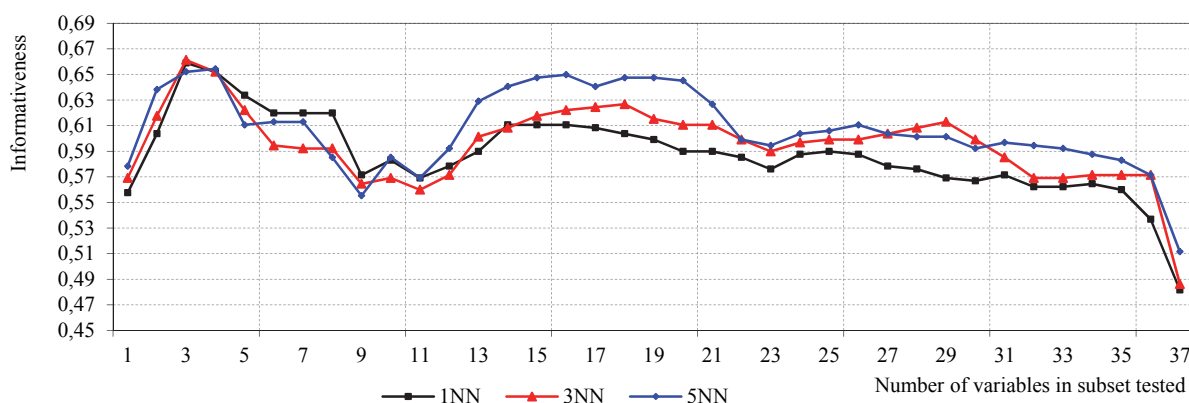
As mentioned above, the power of the relationship between a company's financial performance and these variables, measured by informativeness, reaches the

<sup>1</sup> It is usual not to use even values in order to avoid indecisive situations, and as far as values higher than 5 are concerned, the number of companies in each category of importance is too low.

<sup>2</sup> See <http://www.econ.muni.cz/research/research-centre/>

**Table 1** Values of informativeness in the experiment described

$k$	Best subset		Local maximum	
	Informativeness	No. of variables in subset	Informativeness	No. of variables in subset
1	0.659	3	0.611	14
3	0.661	3	0.627	18
5	0.654	4	0.650	16



**Figure 2** Course of informativeness in the experiment described

value of 0.650. According to the interpretation we accepted, the combination of these 16 variables can thus explain almost 65% of the variability of the dependent variable. This relatively strong dependence is created by the synergistic effects of these variables. However, if we evaluate the relationship between corporate financial performance and each of these variables separately, we witness a completely different situation.

When testing the bivariate connections between the individual variables and the financial performance of companies, it turned out that only six of the 16 variables show a statistically significant relationship with financial performance. These variables are listed in Table 3.

We used Cramer's V and Kendall's tau c coefficients depending on the nature of the data. As the table

**Table 2** Variables chosen by SFFS as the most informative

<i>Variable</i>	<i>Comment</i>
Industry	manufacturing industry, construction
Business entity type	public limited company, private limited company
Size	total number of employees in a company
Span of control	number of management levels to the total number of employees
Ownership type	five types (classified by the number of owners, majority share, etc.)
Owners' origin	domestic owner, foreign owner, domestic and foreign owner
Holding membership	yes – no
Strategy	cost leadership, cost focus, differentiation, differentiation focus
Share of technical-economic employees	share of technical-economic employees in the total number of employees
Share of performance-related pay	average share of the variable wage component in total wages
Employee benefits	amount of funds for employee benefits in relation to personnel costs
Employee fluctuation	less than 2%, 2 to 10%, greater than 10%
Labour productivity	added value per employee
Share of imports	share of imports in the total volume of purchasing raw material, material, intermediate products, etc.
Software applications – MRP module	application of MRP software modules (for production management)
ISO 14000 certificate	holding the certificate of the environmental management system yes – no

**Table 3** Correlations found for the variables chosen by SFFS

<i>Variable</i>	<i>Effect size</i>	<i>p-value</i>	<i>Determination</i>	<i>Interpretation of effect size</i>
Industry	0.230	0.001	5.29%	Low to medium
Business entity type	0.231	0.001	5.34%	Low to medium
Ownership type	0.134	0.053	1.80%	Low
Share of technical-economic employees	–0.080	0.067	0.64%	Low
Share of performance-related pay	–0.099	0.038	0.98%	Low
ISO 14000 certificate	0.241	0.001	5.81%	Low to medium



shows, the found statistically significant relationships are generally low. They range from a negligible 0.08 to a weak or moderate 0.241. This corresponds to the determination of the dependent variable from 0.64% to 5.81%. For almost all tested relationships, there were more than 400 observations available; in one case, there was 338 (share of performance-related pay in wages).

It is clear from the conducted experiment that there is a huge difference between the ability to explain corporate financial performance through the partial effects of the individual variables and the synergistic effects of the same variables.

## 8. Conclusion

The current state of knowledge on the competitiveness factors of companies can be attributed rather to pragmatically and heuristically oriented approaches. They rely mainly on the knowledge of business practice, and often build their conclusions on individual case studies. Moreover, they are primarily focused on qualitative research. Although they bring a number of inspiring findings, their generalisation may not always be sufficiently conclusive.

By contrast, the application of exact approaches enabling quantitative research has been rather scarce in the given field so far. The research described in this paper is based on a much larger number of observations and their subsequent statistical processing, resulting in much higher possibility of the generalisation of the findings.

A broader goal of our experiment, whose results are shown in the presented paper, has been to help extend the application of exact approaches. At the same time, its specific aim was to verify the validity of the hypothesis about the synergistic effect of corporate competitiveness factors, using data from the empirical survey of a representative sample of 432 companies.

It should be made clear that the word hypothesis is not considered here in the strict sense of mathematical statistics. In any case, our experiments have clearly indicated the validity of the hypothesis. However, we do not state intentionally that the hypothesis was unambiguously confirmed or refused, as identical results may not have been achieved with different data. Still, the results of our research have shown that we can almost certainly assume the synergistic effect of the group of variables on a company's financial performance to be always greater than when these variables are considered to operate partially.

In our case, even the highest values of association between financial performance and its predictors were less than 0.250. This means that these variables considered separately can explain at best less than 6%

of the financial performance variation (see Table 3). By contrast, the employment of the SFFS algorithm together with the  $k$ NN classifier helped find a combination of variables that can correctly classify up to 65% of companies in the sample. This is consistent with the results of other studies. Kessler's (2007) model of new business success factors produced  $R^2 = 36.6\%$  for Austrian companies and  $R^2 = 24.2\%$  for Czech companies, while the most statistically significant correlation on the same sample was about  $r = 0.290$ , meaning a determination  $r^2 = 8.4\%$ . These effect sizes are commonly found in the literature, with Huselid's (1995) representative model of ROA depending on human resources management reaching only  $R^2 = 0.130$ . A notable exception is Liu (2004) finding strong predictors of corporate competitiveness in Taiwan industry reaching an effect size of almost  $r = 0.5$  for not only obtaining knowledge capability, but also refining and storing knowledge capability. Moreover, sharing knowledge capability showed in this sample even  $r = 0.972$ .

Apart from this singular result, we can conclude that models considering more potential factors simultaneously are more successful at explaining the variance in competitiveness. This is not surprising, but our study supports this notion by comparing various approaches on the same dataset and also shows that the use of the SFFS algorithm from the SPR field enables us to consider many variables simultaneously and without a predefined model.

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